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Influence of Biogenic Emissions Estimates on Ozone Precursor Control Requirements for Atlanta

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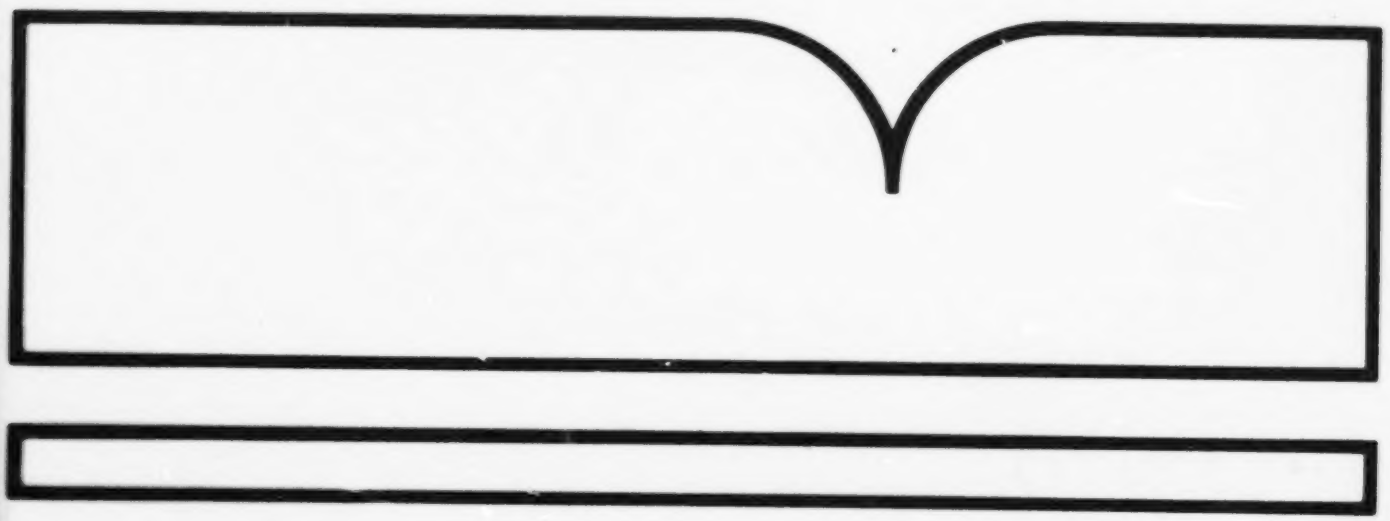

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16. ABSTRACT

Emission estimates of volatile organic compounds (VOC) from natural sources (biogenic emissions) are comparable to emissions from anthropogenic sources in some regions of the U.S. Results from a previous modeling study indicated that inclusion of biogenic emissions can substantially increase anthropogenic VOC control requirements needed to lower peak ozone to the level of the National Ambient Air Quality Standard (NAAQS). The results reported here were developed from analyses based on the Urban Airshed Model (UAM), a gridded photochemical simulation model offering a more complete characterization of the processes leading to ozone formation than the model used in the previous study. Results from a series of simulations conducted in parallel with and without biogenic emissions are presented.

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THE INFLUENCE OF BIOGENIC EMISSIONS ESTIMATES ON OZONE PRECURSOR CONTROL REQUIREMENTS FOR ATLANTA

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INTRODUCTION

Over the past 15 years photochemical air quality simulation models have been used to simulate observed spatial and temporal patterns of ambient ozone, and evaluate the merits of different emissions control approaches for reducing ozone. A coincident increase in our knowledge of atmospheric chemistry responsible for ozone formation has accompanied the use of source driven models which couple atmospheric transport processes with chemistry to provide concentration estimates. Most modeling applications for urban areas included only anthropogenic emissions sources and, typically, control of reactive organic gases (ROG) was shown to be an effective measure for reducing peak ozone. In contrast, the recent modeling work of Chameides et al. (1988) on the Atlanta area suggested that when natural emissions (principally isoprene and alpha-pinene) are included as sources, the effectiveness of anthropogenic ROG control is substantially reduced (relative to the case where natural emissions are not included). The Chameides' work using OZIPM4 (EPA, 1989) suggested that the level of anthropogenic ROG control needed to attain the ozone NAAQS (0.12 ppm) increased from roughly 30% to 70% when natural emissions were included for the modeling day, June 4, 1984. The OZIPM4 is a relatively simple trajectory model, however, and a natural question to be raised is whether similar results would be obtained with a more physically realistic model.

We have produced a similar modeling exercise (expanded to include NOx emissions controls) based on the Urban Airshed Model (UAM) (EPA, 1990a) with carbon bond-4 (CB4) chemistry, EPA's preferred regulatory tool for ozone modeling. The UAM uses a grid based, three dimensional structure which offers more complete characterization of the transport processes, source and concentration distributions relative to OZIPM4. The Atlanta modeling domain (Figure 1) covered an area 160 by 160 km (40x40 4 km cells) and included 5 vertical layers (3 layers above the nighttime inversion height). Simulations commenced at 1200 LST, June 3 and proceeded to 2000 LST, June 4.

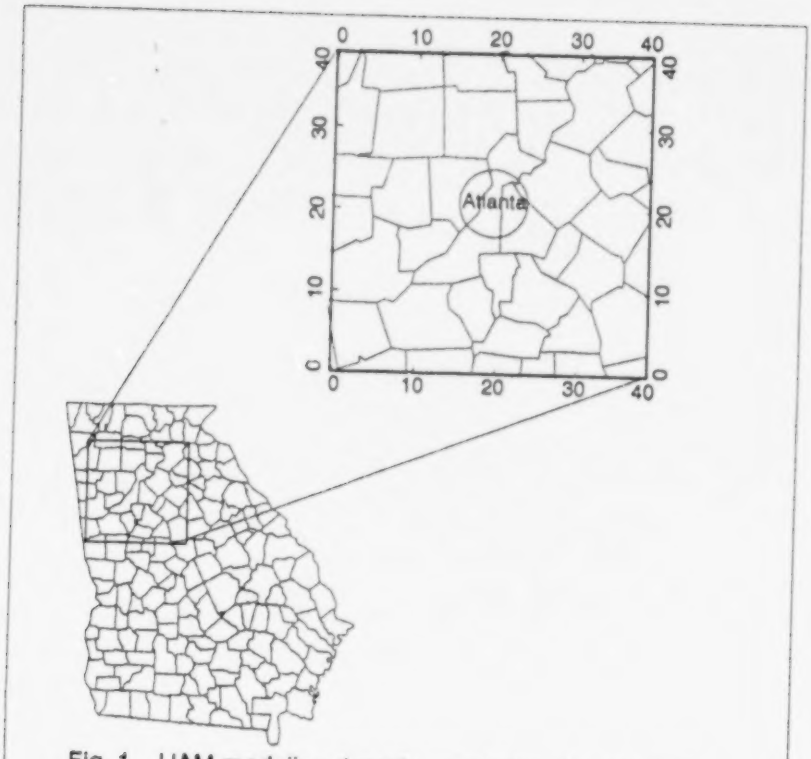

Fig. 1. UAM modeling domain consisting of a 40 by 40 array of 4 km grid cells.

MODEL SETUP

The Atlanta modeling was performed as part of EPA's 5-City UAM study (EPA, 1990b), a demonstration project broad in scope which looked at the feasibility of applying the UAM without conducting a detailed field study as well as various emission control strategy approaches. Accordingly, results reported are intended to represent relative effects (rather than absolutes) incurred as a result of following certain control pathways. Cursory procedural descriptions for developing primary modeling inputs are provided below.

Emissions

Anthropogenic emissions were based on the 1985 National Acid Precipitation Assessment Program (NAPAP) (EPA, 1988). Emissions data were translated to model inputs through a multi-step procedure which performed the necessary gridding, temporalization and speciation. Day specific temperature adjustments were made for mobile source evaporative and running loss emissions. Natural ROG emissions (biogenics) were developed as part of EPA's Regional Oxidant Model (ROM) program (Novak and Regan, 1986). On a domain-wide basis, biogenics accounted for 59% of all ROG emissions. An acknowledged high level of uncertainty (accuracy on the order of +/- 200%) has been associated with biogenic emissions.

Initial and Boundary conditions

Sensitivity to boundary and initial concentrations was mitigated by the large domain and early (June 3) initiation period. The following "clean" initial concentrations were used:

ROG	25 ppbC
ISOPRENE	0.001 ppb
NOx	1 ppb (split 3/4 NO_2, 1/4 NO)
O_3	40 ppb
CO	200 ppb

Boundary concentrations were identical to initial concentrations, except for the following changes: ISOPRENE, 1ppb; ROG, 40ppbC.

Windfield and Mixing Heights

Hourly wind fields (x and y components for each cell) were produced using SAI's diagnostic wind model (DWM) (EPA, 1990a) which is driven by a domain mean wind (based on upper air observations) adjusted for terrain effects and weighted by surface observations (5 NWS/FAA stations). Mixing heights were calculated with the RAMMET meteorological processor (EPA, 1977) using temperature soundings taken from the Athens, Georgia upper-air site. Maximum daily mixing heights reached 1350 m above ground.

RESULTS AND DISCUSSION

A limited performance evaluation (EPA, 1990b) of the model's ability to simulate observed ozone concentrations showed a bias towards underprediction, for three operational ozone monitors (peak observed ozone, 147 ppb; peak simulated, 132 ppb - unmatched in time and space). Model performance was enhanced with a simulation assuming a 50% reduction in wind speed. The available surface wind monitoring network reported wind velocities sampled over short (1-3 minute) time scales. The UAM requires hourly average values; thus, the short averaging period might overstate hourly average velocities. This wind speed simulation was viewed as a sensitivity analysis illustrating the importance of data collecting and reporting practices. The control strategies presented below were based on unadjusted wind speeds, unless otherwise noted.

A series of anthropogenic ROG reduction scenarios across all grid cells and all hours (across-the-board) were simulated for cases with and without inclusion of biogenics. Simulated peak ozone reached a value of only 123 ppb when biogenics were not included (relative to a simulated value of 132 ppb with biogenics and an observed peak of 147 ppb). Given these differences in base case zero control scenarios, all peak ozone model results reported in Figures 2-4 were normalized to the observed ozone value of 147 ppb. These adjustments allowed visual comparisons of peak ozone responses emanating from identical starting points (147 ppb), and also provided a potential calculation technique which accounts for model bias to determine emissions controls needed to demonstrate attainment of the ozone NAAQS.

Peak ozone sensitivity to anthropogenic ROG control was influenced strongly by biogenic emissions (Figure 2). The results clearly show the same general effect observed in the Chameides study - inclusion of biogenic emissions increases the predicted level of anthropogenic VOC control required to reduce peak ozone for Atlanta on June 4, 1984. To reach predicted attainment based on normalized percentage reductions of

peak ozone, the biogenics and nonbiogenics cases require 100% and 62% anthropogenic ROG control, respectively.

A comparison of the relative efficiencies of across-the-board ROG only and NOx only reductions (biogenics included for both cases) show peak ozone to be more responsive to NOx emissions changes (Figure 3). Clearly, the degree of ROG loading, due largely to the biogenics fraction, is creating an atmosphere (for Atlanta on the day modeled) which is NOx limited with respect to ozone sensitivity.

Given the uncertainty in characterizing prevailing wind fields, the modeling runs shown in Figure 2 were repeated with the adjusted, reduced speed wind field. The base case simulation with zero control resulted in peak ozone values of 147 ppb and 129 ppb (unmatched in space and time) for the biogenics and nonbiogenics cases, respectively. Results from identical VOC control strategy simulations with the new wind field (Figure 4) suggest a reduced impact, relative to the original windfield, on control calculations due to biogenic emissions. Simulations based on the new windfield produced VOC control levels of 62% and 53% to reach attainment for biogenic and nonbiogenic cases, respectively (compared to 100% and 62% with the original windfield). Rather than deciding which wind field is more representative, the new wind field might be viewed as an additional modeling day with a slower mean trajectory. In this scenario anthropogenic emissions now comprise a greater fraction of total VOC emissions because the slower wind speed increases the residence time ratios of anthropogenic to biogenic emissions, relative to the original windfield with higher wind speeds. Thus, it is evident that meteorological variability influences ozone precursor control calculations. Certainly, multiple episodes will need to be examined when control calculations are performed.

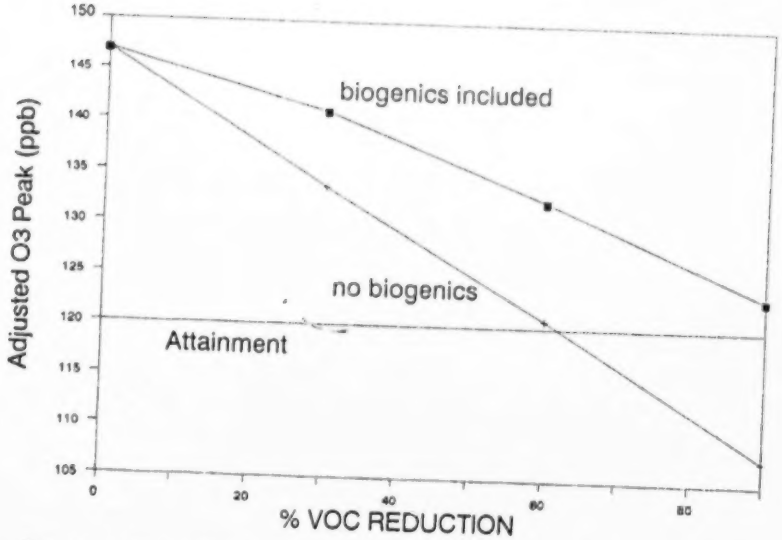

Fig. 2. Comparison of peak ozone sensitivity to VOC emissions reductions (man made) with and without biogenics.

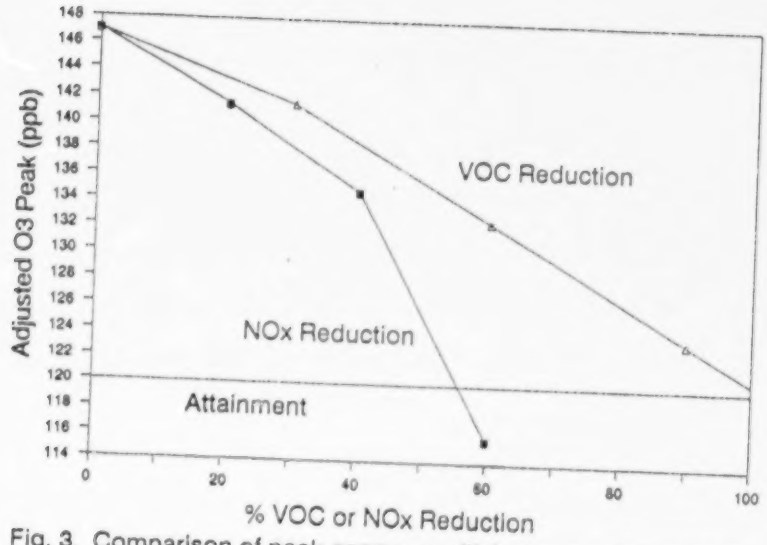

Fig. 3. Comparison of peak ozone sensitivity to changes in VOC and NOx emissions reductions (biogenics included).

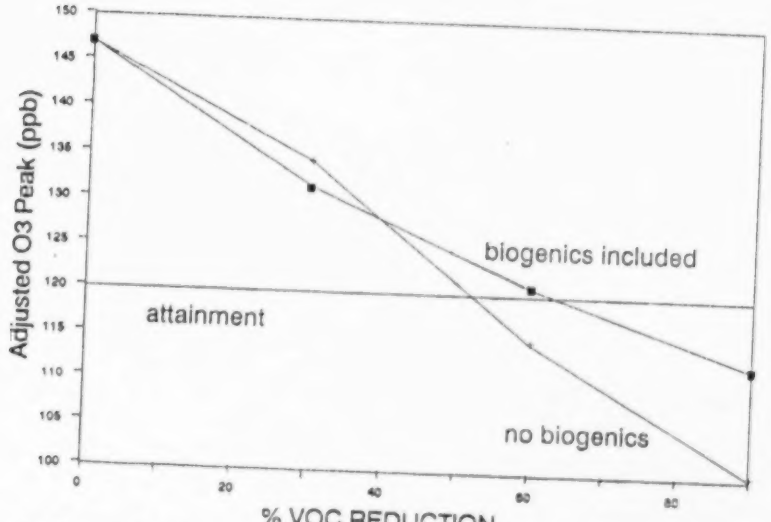

Fig. 4. Comparison of peak ozone sensitivity to anthropogenic VOC reductions with and without biogenics. These simulations were based on the adjusted (50% speed reduction) wind field.

CONCLUSIONS

Grid based modeling results presented here support Chameides' earlier findings - inclusion of biogenic emissions increases the level of anthropogenic ROG control required to reduce peak ozone in Atlanta for the modeled day, June 4, 1984. Biogenic emissions must be considered as part of the total emissions loading when the effectiveness of anthropogenic control strategies is evaluated through modeling. The results indicate that NOx based control approaches may be more effective in reducing peak ozone in certain areas, using Atlanta as an example.

How effective would NOx strategies be in other locations? It must be emphasized that these results may not be representative of all situations. Atlanta is dissimilar from other major urban areas in several ways. First, biogenic emissions may be higher in the southern U.S. due to the relatively dense distribution of high emitting vegetation types. Second, biogenic emission models exhibit strong temperature sensitivity, and southern U.S. areas are characterized by high summer temperatures that lead to high emission rates. Third, Atlanta is a predominantly residential/commercial city with a limited urban core and more diffuse residential areas relative to other major urban areas. Although NOx control was shown to be effective for Atlanta, recent similar UAM simulations performed on Dallas-Fort Worth and St. Louis (EPA, 1990b) have shown that aggressive NOx control can potentially offset benefits resulting from ROG control.

Additional analyses, modeling as well as observational, need to be conducted on other cities and combined with regional scale analyses (to better characterize background hydrocarbon levels) to determine the most effective control pathways for reducing ozone. Before a good deal of confidence can be associated with the quantitative capability of those analyses, the uncertainty of natural (as well as anthropogenic) emissions must be reduced. The importance of adequate meteorological data and its attendant influences on control strategy results and the model's ability to depict proper response behavior can not be understated.

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